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(54) IMPROVEMENTS IN SERVOMECHANISMS

(71) We, THE RANK ORGANISATION LIMITED, of Millbank Tower, Millbank, London, S.W.1, a British Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to servomechanisms and particularly though not exclusively, to servomechanisms for use in controlling the position of the movable element or elements of a zoom lens. Embodiments of the invention find utility, however, in any application where it is desired to move an element within a restricted range.

One of the problems associated with servomechanisms when used in this way is that there is frequently an unacceptable shock as the controlled element reaches the end of its limited travel. In the case of the movable element of a zoom lens, for example, the range of movement is defined between end stops and it is essential to avoid damaging the lens element as it strikes the end stop and, no less important, to avoid the jolt which is transmitted to the picture being taken while zooming, and the resulting acoustic noise picked up by studio microphones.

Various systems have been previously proposed to overcome this disadvantage which is particularly acute when the control signal input of the servomechanism is a velocity demand signal since the possibility of driving the controlled element at full speed into one of the end stops is quite high. One previously proposed arrangement for overcoming the problem mentioned above is described in British Patent No. 1,350,084; this arrangement utilizes a position sensitive device to detect when the controlled element is a predetermined distance from the end stops and acts to apply an overriding control to the servomechanism to reduce the velocity demand input to a preselected acceptable value. This arrangement was not entirely satisfactory, however, since no account was taken of the velocity at which the controlled element was travelling as it passed the critical point approaching an end stop. In order for the useful range of the controlled element to be fully utilised it was necessary to locate the critical position fairly close to the end stops and this gave rise to unacceptable jerkiness when the controlled element passed the critical position at maximum velocity since the deceleration in this case was considerably higher than the deceleration which would occur if the controlled element were travelling at a lower velocity. The reason for this is that in this prior system the "braking distance" over which the controlled element slowed down to the preset approach speed for its approach to and impact against the end stops was a set distance which did not vary with the velocity of approach of the controlled element as it passed the critical position.

According to the present invention there is provided a servomechanism for controlling the movement of a movable element in each of two opposite directions between two end positions, having control means for producing a velocity demand signal for selecting a desired velocity of the controlled element, means sensitive to the position of the controlled element and operative to produce a signal representing the position of the controlled element, and a deceleration control circuit, including a comparison device, sensitive to the velocity demand signal and to the position signal and operative to cause the controlled element to decelerate substantially at a predetermined rate, which rate is independent of the selected velocity of the controlled element prior to the commencement of deceleration, as it approaches one or other of the said end positions, if the velocity of the controlled element is above a predetermined value.

Embodiments of the present invention are thus capable of effectively adjusting the critical position at which the controlled movable element begins to slow down, in dependence on the velocity of the controlled

element so that the rate of deceleration is substantially the same regardless of the velocity at which the controlled element is travelling in the middle of its range of travel and as it initially approaches one of the end positions of its range of travel.

In one embodiment of the present invention the deceleration control circuit is so arranged that the velocity of the controlled element is reduced to at most the said predetermined velocity when it reaches one of the said end positions. In such an embodiment the velocity of the controlled element is normally reduced to less than the predetermined velocity before it reaches either end position, if the velocity demanded by the control means is greater than the said predetermined velocity. If the demanded velocity of the controlled element is less than this predetermined velocity it is allowed to approach the end position at the velocity determined by the said control means.

In an alternative embodiment the deceleration control circuit is so arranged that the velocity of the controlled element is reduced to substantially the predetermined value when it reaches either of the end stops. In other words the servomechanism is so arranged that the velocity of the controlled element is always substantially the same as it strikes an end stop defining the end position of the range of movement of the controlled element.

The control means preferably includes an amplifier the output from which represents the said velocity demand signal, and the deceleration control circuit includes at least two impedances coupled to receive the output signal from the amplifier, the impedances being either linearly or non-linearly dependent on the output signal from the amplifier and forming part of a control loop which feeds signals to and receives signals from the comparison device of the deceleration control circuit. The signals received from the said comparison device are preferably only received when the controlled element approaches the end positions so that the said two impedances have no effect on the operation of the servomechanism in the mid range of movement of the controlled element. The linear or non-linear characteristics of these impedances, however, control the relationship between velocity and position of the controlled element during its deceleration so that the deceleration may be at a constant (linear) rate or at a varying (non-linear) rate depending on the characteristics of the impedances.

In a preferred embodiment there are provided attenuators coupled to the output of the said amplifier producing the said velocity demand signal from the said control means, the attenuators being effective, when operated, to attenuate the said velocity demand signal from the said amplifier. The output signal from the said amplifier controls the operation of the remainder of the servomechanism and accordingly attenuation of this output will cause the desired deceleration of the controlled element.

In the preferred embodiment mentioned above there is provided a second amplifier coupled to receive signals from the said two impedances at one input and signals from the said comparison device at the other input, the output being coupled to control the operation of the said attentuators. Since the comparison device only produces output signals near the ends of the range of movement of the controlled element the output of the second amplifier is insufficient to operate the attenuators when the controlled element is in the middle of its range.

Preferably the comparison device comprises a pair of rectifiers coupled in parallel with opposite polarity, signals representing the said demand signal being fed to one of the junctions between the two rectifiers and the signals representing the position of the controlled element being fed to the other junction of the rectifiers, the anodes of the two rectifiers being positively and negatively biased respectively. Thus one or other of the rectifiers will conduct when the potential difference across it, determined effectively by the demand signal and the position signal, is such that the rectifier is forward biased.

The attenuators preferably comprise transistors which are controlled to conduct when the comparison device produces a signal to the second amplifier.

One embodiment of the invention will now be more particularly described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a block diagram illustrating the general arrangement of one embodiment of the invention;

Figure 2 is a schematic circuit diagram of a particular example of the embodiment of Figure 1; and

Figure 3 is a diagram illustrating the variation of the speed of a controlled element with respect to the position thereof, at various settings of the control element within a restricted range.

Referring now to Figure 1 there is shown a block diagram of a circuit for controlling a movable element of a zoom lens. The movable element is controlled from a manually operable control device 11 which provides a signal in dependence on the required velocity of the controlled element. The signal is passed along a line 12 *via* a circuit 13 to a servo actuator 14. The servo actuator 14 operates to produce a mechanical movement of a controlled element 15. A position sensor 16 is coupled to detect the movement of the controlled element 15 and

to provide an electrical signal along line 17 to a comparison device 18 which will be described in greater detail below. The position sensor 16 may equally well be coupled to the actuator 14 either directly or via a mechanical transmission. This alternative, of course has no effect on the manner of operation of the system.

The output from the circuit 13, in addition to being coupled to the servo actuator 14 is also coupled to a pair of attenuators 19, 20 respectively, and an impedance circuit 10 the operation and purpose of which will be described below.

The output of the impedance circuit 10 is coupled *via* a resistor 21 to one input of a high gain difference amplifier 22 the other input of which is connected to the comparison device 18. The amplifier 22 is coupled in a feedback configuration with a circuit 23 so that the connection between the input of the amplifier 22 and the comparison device 18 provides a two way path for signals. That is, the output of the amplifier is fed to an input of the comparison device and the comparison device is connected to one input of the amplifier 22. The output of the amplifier 22 also passes *via* an attenuator 24 to control gates of the attenuators 19 and 20.

Referring now to Figure 2 there is shown a schematic circuit diagram illustrating in greater detail the embodiment illustrated in Figure 1, in which the circuit 13 comprises an amplifier 33, a feedback resistor 34 and an impedance element in the form of a resistor 35 coupled between the output of the amplifier 33 and the position at which the feedback resistor 34 is connected. The impedance network 10 is coupled at the same point of the output of the circuit 13 as the feedback resistor 34 and, in this embodiment, comprises two resistors 10*a* and 10*b* connected in series with a reference potential, which may be earth.

The junction of the two resistors 10*a* and 10*b* is coupled *via* a resistor 21 to one input of the difference amplifier 22 the output of which is fed back *via* a resistor 23 to the other input thereof. The output of the amplifier 22 is also fed, as mentioned above, *via* an attenuating network 24 to the control gates of two attenuators 19, 20 which in this embodiment are the bases of two respective transistors 36 and 37. The emitters of the two transistors are coupled together and to a reference potential, and the collectors of the two transistors 36 and 37 are respectively connected to diodes 38 and 39 which are connected, with opposing polarities, to the output of the circuit 13.

The second input of the amplifier 22 is also coupled to one side of the comparator device 18 which in this embodiment comprises a pair of diodes 40 and 41 coupled in parallel with opposite polarity to each other, one junction between the diodes 40 and 41 being directly coupled to the input of amplifier 22, and two resistors 43, 44 being connected to respective diodes 40, 41 and to the wiper of a potentiometer 42 connected between positive and negative reference potentials.

The potentiometer 42 is coupled to the controlled element which, for example, may be the movable element of a zoom lens, so that the signal from the potentiometer provides an indication of the position of the movable controlled element. Between the diode 40 and the resistor 43 there is connected one end of a resistor 45 the other end of which is connected to a positive reference potential, and between the diode 41 and its associated series transistor 44 there is connected one end of a resistor 46 the other end of which is connected to a negative reference potential.

The operation of the circuit described above is as follows:—

A signal from the control means 11 is passed to the input of the amplifier 33 where it is amplified and fed to the servo actuator 14 to effect movement of the controlled element. If neither of the attenuators 19 and 20 are operating, that is if the transistors 36 and 37 are both non-conductive, then the signal from the control device 11 will be passed substantially unmodified to the servo actuator 14.

The impedance network 10, being fed from the output of the circuit 13 thus provides a signal to the input of the amplifier 22 which depends solely on the value of the output from the circuit 13.

At the middle of the range of movement of the controlled element the potentiometer 42 will provide a signal midway between the reference potentials supplied to the resistors 45 and 46 and accordingly neither of the diodes 40 or 41 will conduct. The second input to the amplifier 22 is thus determined solely by the feedback through the resistor 23 and the amplifier 22 accordingly acts simply as a voltage follower. The output of the amplifier 22 is thus determined by the impedance network 10 and, after attenuation at the attenuation network 24, the signal from the output of the amplifier 22 is insufficient to render either of the transistors 36 or 37 conducting.

As the controlled element approaches one end of its travel, the signal applied to the comparison device 18 from the potentiometer 42 will begin to approach the reverse biasing voltage applied to one of the diodes 40 and 41 by the amplifier 22 and the biasing resistors 45 and 46. The signal from the amplifier 22 depends on the value of the signal from the control device 11 so that the precise position at which one of the diodes 40 or 41 becomes forward biased will depend

not only on the position of the controlled element but also on the velocity at which it is travelling.

When one of the diodes 40 or 41 becomes forward biased there is an additional input signal to the amplifier 22 and this causes an increase in the output of the amplifier 22; thus when one of the diodes 40 or 41 is conducting the amplifier 22 acts as a summing amplifier with source impedances determined by the resistors 43 and 45 or 44 and 46 and source voltages or currents determined by the setting of the control device 11 and the fixed reference or bias levels applied to the resistors 45 and 46. The voltage level at the output of the amplifier is sufficiently high, when either of the diodes 40 or 41 is conducting to switch the respective transistor 36 or 37 to a conducting state thereby closing a path to earth and attenuating the signal on the line 12 between the control device 11 and the servo actuator 14.

The precise degree of attenuation is determined by the voltage drop across the attenuator 19 or 20, this in turn being determined by the voltage drop across the diode together with the bottoming voltage of the respective transistor. The velocity of the controlled element 15 thus decreases. The feedback loop of the amplifier 33 generates an increased error signal at the input of the amplifier 33 and this amplifier thus becomes saturated. The output impedance of the circuit 13 thus increases to a value determined by the resistor 35.

The impedance network 10 following this impedance change determines the shape of the curve of fall off of the signal on line 12.

On reversing the polarity of the velocity input signal from the control device 11 after the servo has reached the end position, it will be appreciated that the transistor which was previously conducting is now biased off and therefore cannot affect the servo actuator input signal. The servo actuator can therefore operate to move the controlled element away from the end position at, if desired, up to the maximum velocity.

With reference to Figure 3 there is shown a diagram illustrating the velocity of the controlled element with respect to position. For example, considering line A as the maximum velocity of the controlled element; as the controlled element approaches the end position the comparison network 18 will cause a decrease in the velocity when the controlled element gets to the position marked A^1. If the velocity is lower than the maximum velocity, say that indicated by the line B, then the controlled element will be allowed to get to the position B^1, which is closer to the end position than that indicated by the position A^1 before the comparison device operates to start the deceleration of the controlled element. In both cases the deceleration takes place at the same rate as shown by the slope of the line. At a lower speed, indicated by the line C the controlled element will not be slowed down at all as it approaches the end stop as the speed C represents the maximum allowable speed of approach of the controlled element. It could be arranged for the locus of the points A^1, B^1, where the comparison network would first cause deceleration of the controlled element, to be the same slope as the rate of deceleration of the controlled element when the comparison network has operated. In this case the controlled element is always travelling at the same speed as it strikes the end stop, whereas in the diagram shown in Figure 3 the speed of the controlled element as it strikes the end stop is less than the maximum allowable speed if the demand speed from the control device 11 is greater than the maximum allowable speed. The same situation obtains in reverse at the other end of the range of movement as is shown by the lines A_1, B_1, and C_1 of Figure 3. It should be noted that the shape of these lines need not necessarily be the same as that of lines A, B and C if a different stopping characteristic is desired at the two ends of the range of movement of the controlled element.

The above embodiment is illustrative only and modifications may be made within the scope of the invention. In one such modification (not shown), the diodes 38 and 39 of Fig. 2 are coupled to the line 12 via a resistor, whose value may be selected so that, in conjunction with the diodes 38, 39 and transistors 36, 37, the overall resistance gives a desired final speed; the resistor could of course be variable to give manual cotnrol of these factors. Likewise, a selected resistance may be interposed between the diodes 40, 41 and the amplifier 22 of Fig. 2. This effectively increases the input impedance of the amplifier 22 and thus reduces its closed loop gain, which makes the transition from the selected speed to deceleration less abrupt.

A further advantage of the invention is that in many applications the actuator or controlled element is provided with a position transducer for example to provide a reset signal to a position servo control. Thus the invention allows such a system to be converted easily to a rate servo with end stop velocity limitation by the substitution of a limited number of components and without the use of complex components such as multigang potentiometers.

WHAT WE CLAIM IS:—

1. A servomechanism for controlling the movement of a movable element in each of two opposite directions between two end

positions, having control means for producing a velocity demand signal for selecting a desired velocity of the controlled element, means sensitive to the position of the controlled element and operative to produce a signal representing the position of the controlled element, and a deceleration control circuit, including a comparison device, sensitive to the velocity demand signal and to the position signal and operative to cause the controlled element to decelerate substantially at a predetermined rate, which rate is independent of the selected velocity of the controlled element prior to the commencement of deceleration, as it approaches one or other of the said end positions, if the velocity of the controlled element is above a predetermined value.

2. A servomechanism as claimed in Claim 1, in which the deceleration control circuit is so arranged that the velocity of the controlled element is reduced to at most the said predetermined velocity when it reaches one of the said end positions.

3. A servomechanism as claimed in Claim 1, in which the deceleration control circuit is so arranged that the velocity of the controlled element is reduced to substantially the predetermined value when it reaches either of the end stops.

4. A servomechanism as claimed in any of Claims 1, 2 or 3 in which the means sensitive to the position of the controlled element comprises a potentiometer or position transducer operative to produce an electrical signal in dependence on the position of the controlled element within its range of movement.

5. A servo mechanism as claimed in any of Claims 1 to 4 ,in which the control means includes an amplifier the output from which represents the said velocity demand signal, and the deceleration control circuit includes at least two impedances coupled to receive the output signal from the amplifier, the impedances being either linearly or non-linearly dependent on the output signal from the amplifier and forming part of a control loop which feeds signals to and receives signals from the comparison device of the deceleration control circuit.

6. A servomechanism as claimed in Claim 5, in which there are provided attenuators coupled to the output of the said amplifier producing the said velocity demand signal from the said control means, the attenuators being effective, when operated, to attenuate the said velocity demand signal from the said amplifier.

7. A servomechanism as claimed in Claim 6 ,in which there is provided a second amplifier coupled to receive signals from the said two impedances at one input and signals from the said comparison device at the other input, the output being coupled to control the operation of the said attenuators.

8. A servomechanism as claimed in any of Claims 1 to 7, in which the comparison device comprises a pair of rectifiers coupled in parallel with opposite polarity, signals representing the said demand signal being fed to one of the junctions between the two rectifiers and the signals representing the position of the controlled element being fed to the other junction of the rectifiers, the anodes of the two rectifiers being positively and negatively biased respectively.

9. A servomechanism substantially as hereinbefore described with reference to, and as shown in, the accompanying drawings.

H. G. AMMAN,
Agent for the Applicants.

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FIG. 1.

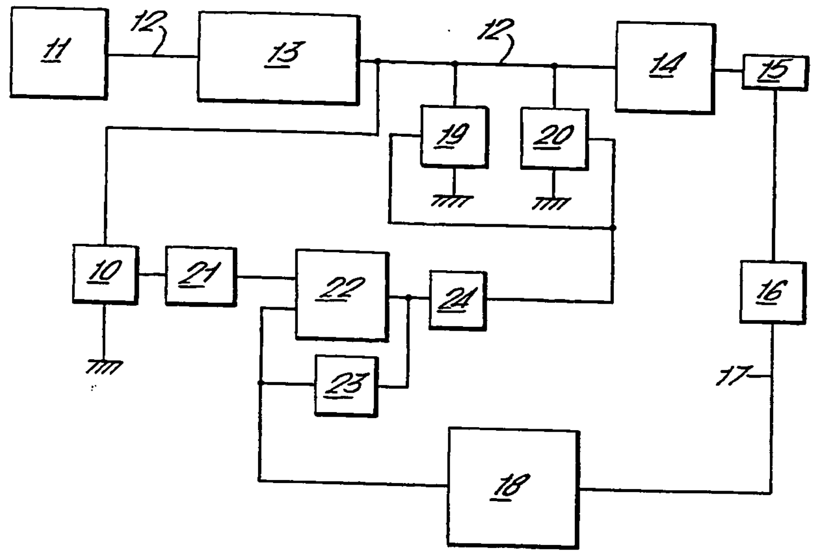
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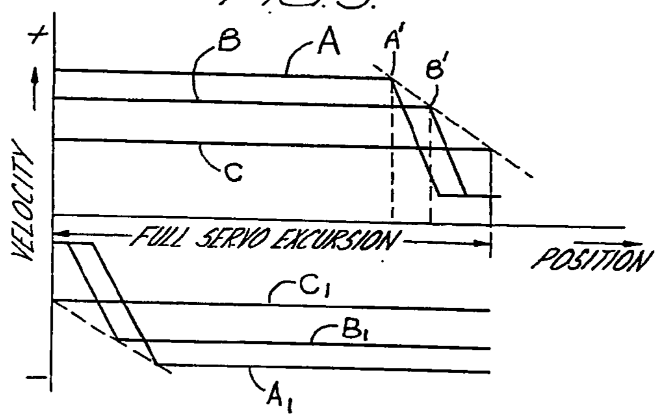
FIG. 3.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B
A
A'
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C
VELOCITY
FULL SERVO EXCURSION
POSITION
C1
B1
A1
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1382057 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

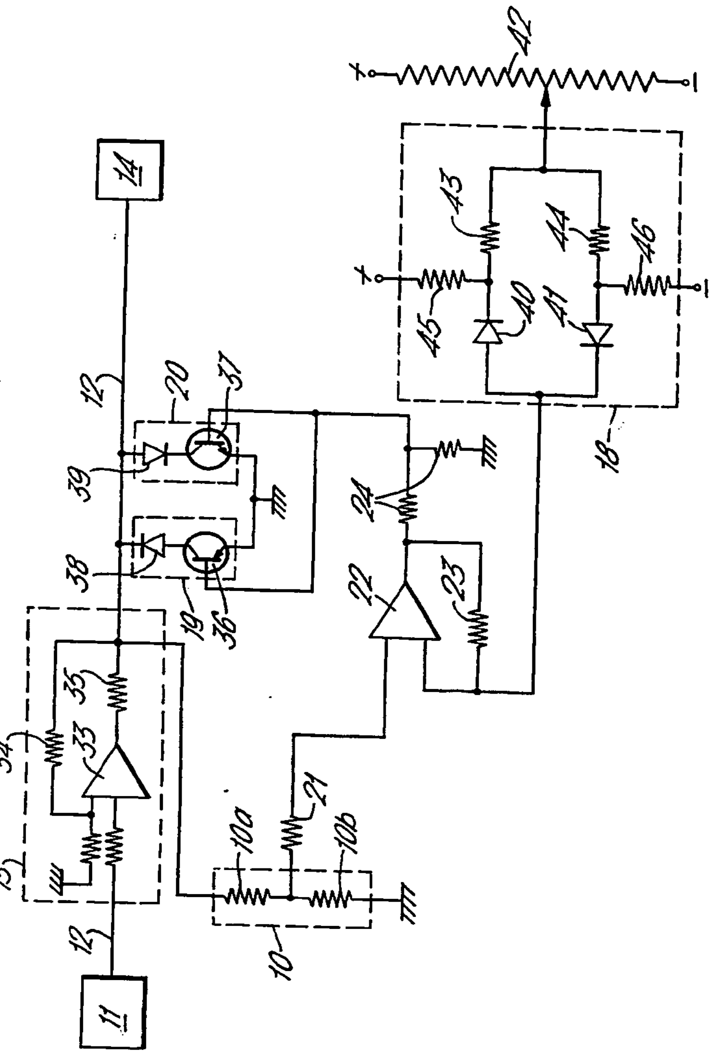

FIG.2.